Observed earthquake rates in the 1850-2006 California catalog

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Outline

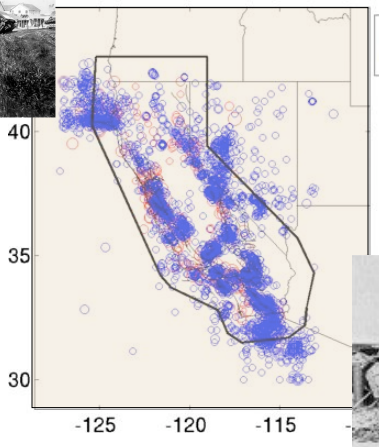
- Catalog Compilation
- Correcting for magnitude rounding and errors
- Catalog incompleteness
- Measuring *b* values
- Inclusion of aftershocks ?
- Preliminary Results

Compilation of the California catalog

Years	Southern California	Northern California
1850-1932	CDMG catalog	CDMG catalog
1932-1972	Newly revised SCECDC catalog + CDMG + UCLA	CDMG catalog
1973-2006	SCECDC + HRV CMT catalog	ANSS + HRV CMT catalog

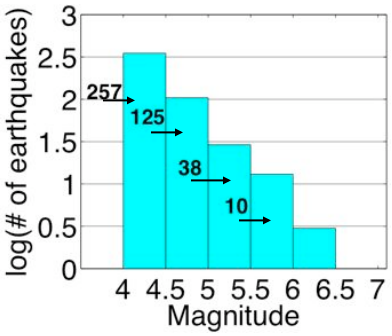
M≥4 catalog, 1850-2006

1906

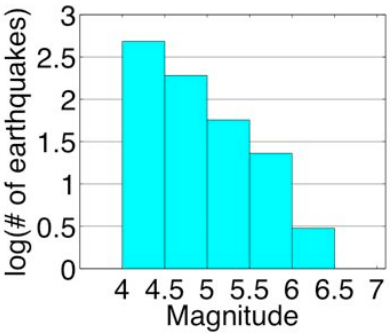


1933

The Problem of Magnitude Rounding

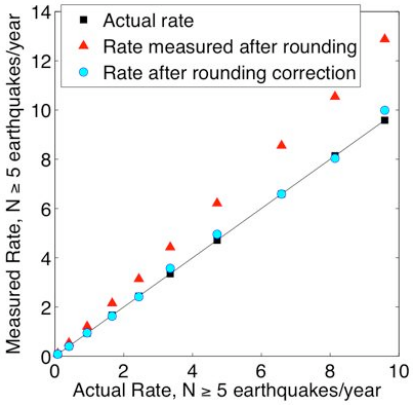


Magnitude distribution before rounding



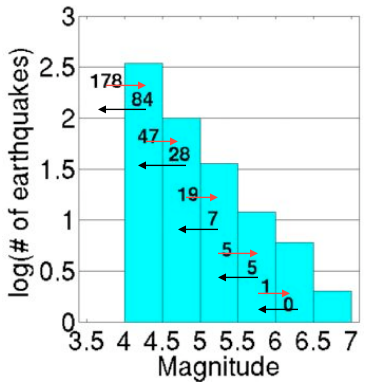
After rounding M<5.5 to closest 0.5

Correcting for magnitude rounding

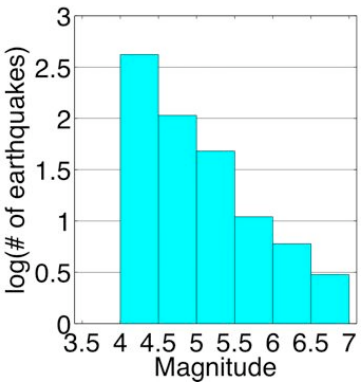


In Monte Carlo trials each rounded magnitude is randomly replaced with a magnitude drawn from a Gutenberg-Richter distribution

The problem of magnitude error

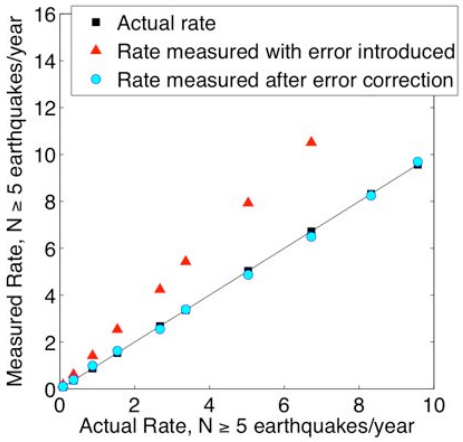


True magnitude distribution



Magnitude distribution after Gaussian error, $\sigma = 0.25$

Correcting for magnitude error



Each magnitude, *M*, is replaced by $M - b\sigma^2/2(\log_{10}(e))$

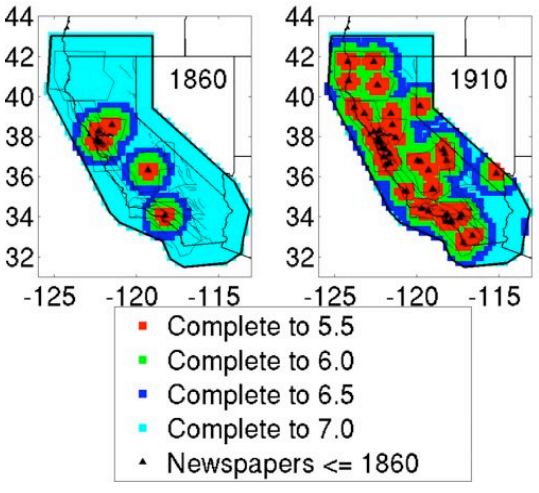
(*Tinti and Mulargia*, 1985)

Assignment of magnitude error for each earthquake

Earthquakes	Error assignment
<1932	*Bakun and Wentworth (1997)*
>1932, So Cal	From amplitude tables
>1972, No Cal	Listed in USGS catalog
Harvard CMTs	σ = 0.09 (*Kagan et al.*, 2006)
Unknowns, < 1932	σ = 0.333
Unknowns, 1932-1972	σ = 0.222
Unknowns > 1973	σ = 0.111

Historical catalog completeness:

1) Assign completeness at points from newspaper locations



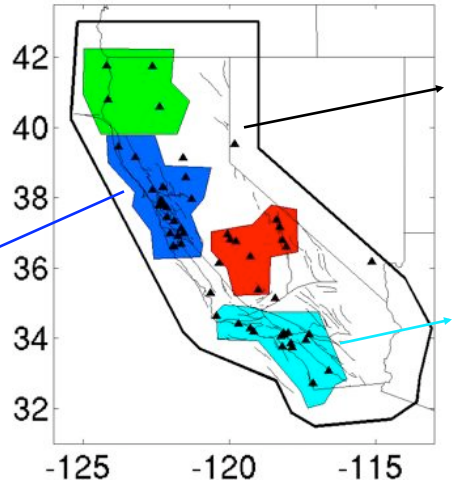
- Inspired by method of *Schorlemmer et al.*
- Assuming MMI ≥ 5 noted
- *Bakun and Wentworth* (1997) magnitude/ MMI relation

Historical catalog completeness:

2) Draw regions around areas of similar completeness

SF area completeness

1850-55	7.0
1855-65	6.7
1865-85	5.8
1885-90	5.7
1890-1942	5.6



Full State

1850-1905	7.0
1905-1910	6.9
1910-1942	6.6

LA area completeness

1850-70	7.0
1870-75	6.4
1875-90	5.9
1890-95	5.8
1895-1905	5.7
1905-1942	5.6

Instrumental catalog completeness:

-Plan to use similar method, with instrument locations

But for now --

1942-1990	**Statewide**	**5.5**	**Trial & error**
1990-2006	**Statewide**	**5.0**	**Trial & error**

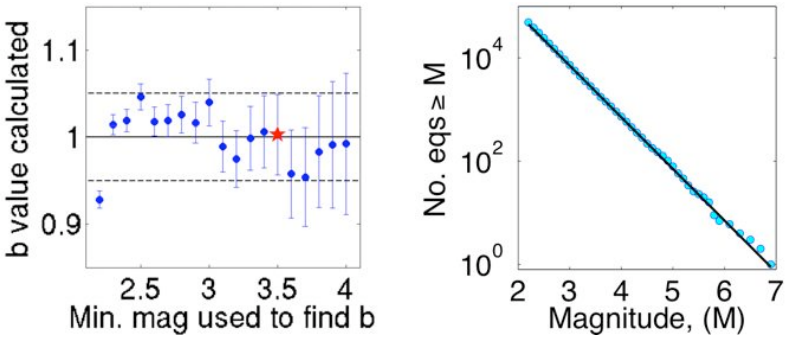
The *b* value

- **Gutenberg-Richter relationship: log(N) = a - *b*M.**

***b* value is used for:**

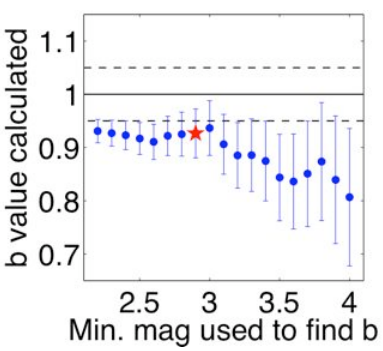
- Better constraining the rates of large earthquakes
- Extrapolating rates of the largest earthquakes
- Building background and fault magnitude distributions
- Correcting for rounding and magnitude errors

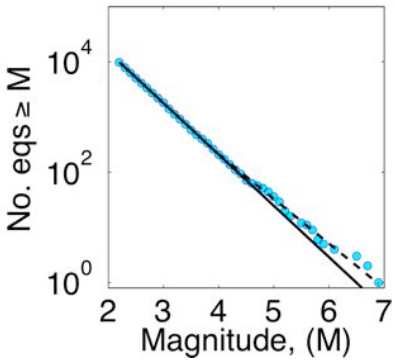
The value of *b* can be solved accurately from the modern catalog



The 1990-2005 catalog indicates that ***b*=1.0** for the state of California

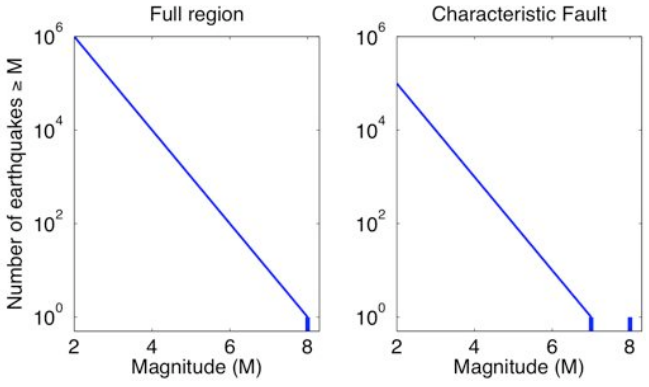
The declustered 1990-2005 catalog (via *Gardner and Knopoff* (1975)) gives b = 0.93 overall, b=0.81 for M≥4





The 1850-2002 declustered catalog and completeness thresholds of NHM 2002 give b = 0.8

Do magnitudes on individual faults follow the GR distribution?

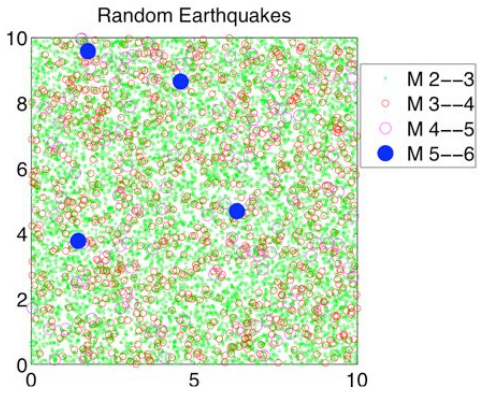


In the characteristic earthquake hypothesis (*Wesnousky et al*. 1981) earthquakes on faults have a higher probability of having the characteristic magnitude than GR predicts

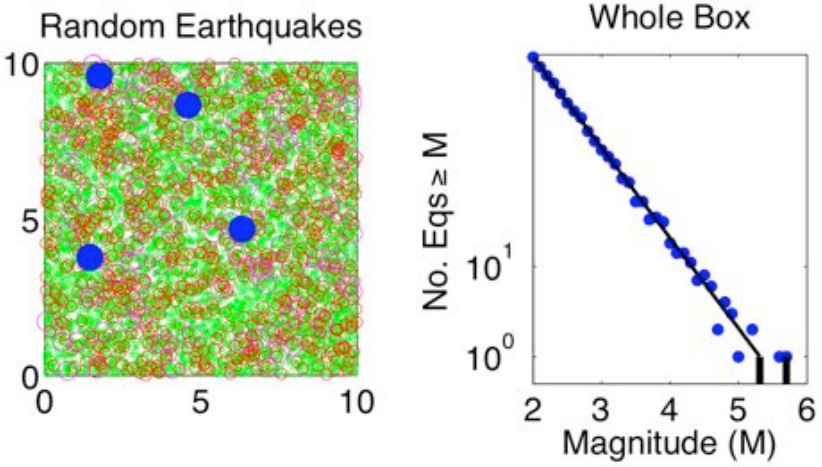
Problem: The Characteristic observation results from sampling bias

Demonstration:

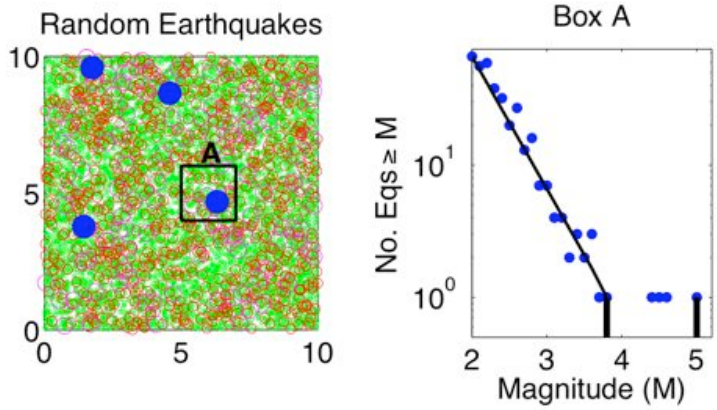
1) We generate earthquakes that are random in location and GR magnitude



2) If we sample the whole box we get a Gutenberg-Richter distribution

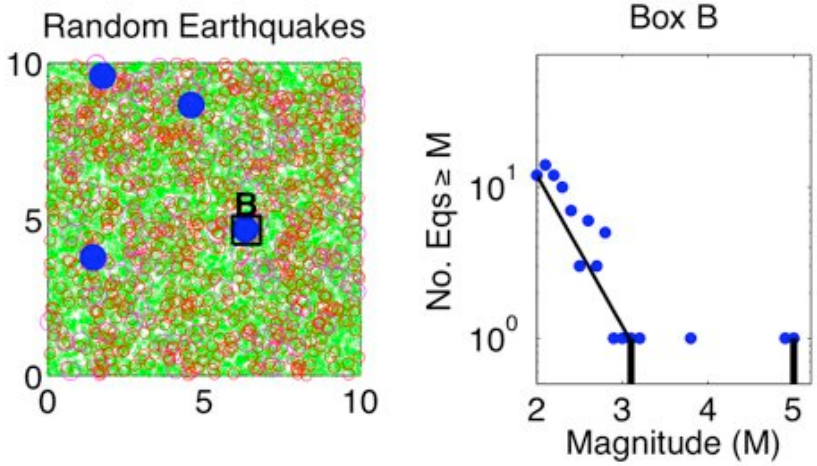


3) If we sample a sub-region *known* to have a large earthquake we get a "characteristic" distribution

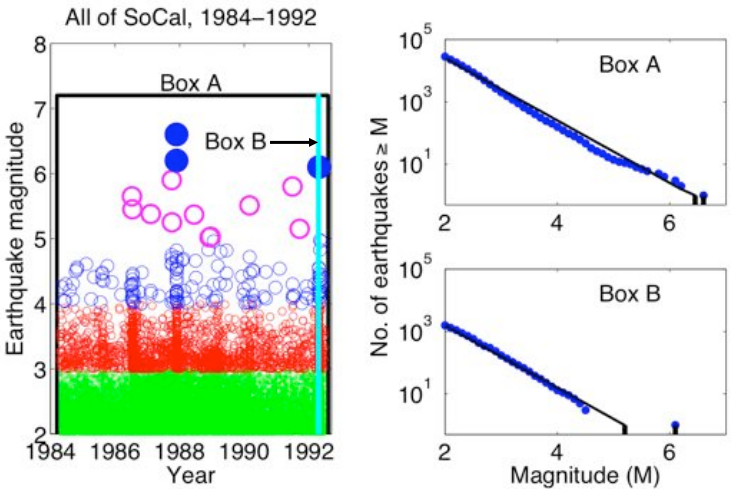


This is equivalent to drawing a narrow box around a fault with a known large earthquake

4) We can make the distribution as extreme as we want by just shrinking the box



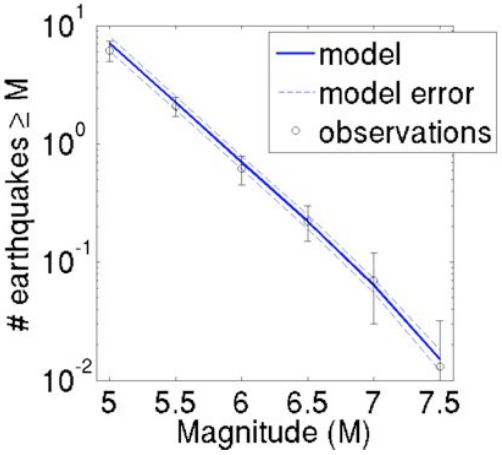
The characteristic distribution can also be obtained by sampling earthquakes over all space but over a limited time



Should aftershocks (and foreshocks) be included in the time independent rate calculation?

- Aftershocks work on weakened buildings
- 15% of earthquakes are preceded by a foreshock that is within one magnitude unit => foreshock pre-weakens the building
- A site may experience a higher intensity from an aftershock than from a mainshock (e.g. Big Bear)
- Aftershocks contribute equally to the moment balance and cannot be differentiated geologically

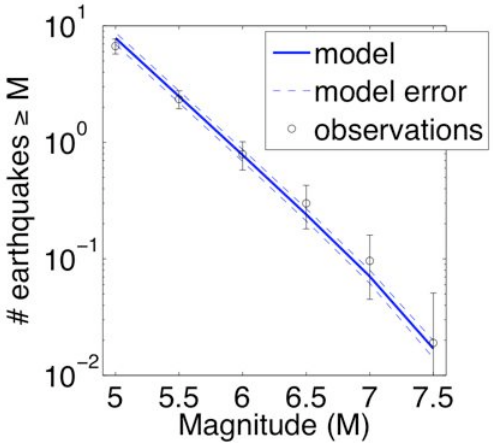
Seismicity rates: Final Results



- Rounded magnitudes corrected for ✔
- Magnitude error corrected for ✔
- New completeness thresholds used ✔
- *b* =1.0 used ✔

6.77 ± 0.85 M≥ 5 eqs/year, non-declustered catalog

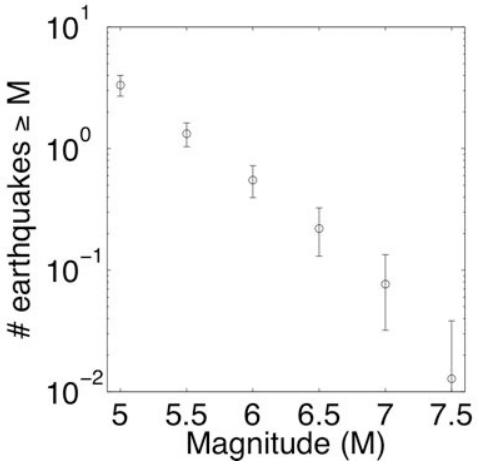
Seismicity rates: Results w/o corrections



- ~~Rounded magnitudes corrected for~~ ✘
- ~~Magnitude error corrected for~~ ✘
- New completeness thresholds used ✔
- *b* =1.0 used ✔

7.85 ± 0.92 M≥ 5 eqs/year, non-declustered catalog

Seismicity rates: Declustered catalog



- Rounded magnitudes corrected for ✔
- Magnitude error corrected for ✔
- New completeness thresholds used ✔

3.3 ± 0.65 M≥ 5 eqs/year, declustered catalog

Conclusions

- Correcting for rounding and magnitude errors decreases the California seismicity rate by 15%.
- Using re-calculated completeness thresholds increases the seismicity rate by 42%.
- A *b* value of 1.0 is found for California. This changes the ratio of smaller to larger earthquakes from the 2002 NHM model.

Appendix: Observed seismicity rates

>=Mag	Corrected catalog	Uncor. Catalog	Declustered catalog
5.0	6.15 ± 0.9	6.7 ± 1.0	3.3 ± 0.63
5.5	2.09 ± 0.38	2.35 ± 0.4	1.3 ± 0.29
6.0	0.62 ± 0.18	0.79 ± 0.2	0.55 ± 0.16
6.5	0.22 ± 0.10	0.3 ± 0.1	0.22 ± 0.09
7.0	0.07 ± 0.05	0.096 ± 0.05	0.077 ± 0.05
7.5	0.013 ± 0.012	0.019 ± 0.02	0.013 ± 0.012

Catalog Completeness used for the 2002 National Hazard Map, California Region

years	$\mathbf{M_{min}}$ used by NHM 2002	$\mathbf{M_{min}}$ recommended by Toppozada
1850-1900	6.0	> 6.0
1900-1932	5.0	6.0
1933-2006	4.0	<6.0 ?

Magnitude completenesses used appropriate for the San Francisco Bay Area -- but not for the rest of the state